

INK JET RECORDING METHOD,  
RECORDING APPARATUS AND DATA PROCESSING METHOD

FIELD OF THE INVENTION AND RELATED ART:

5           The present invention relates to an ink jet  
recording method, a recording device and a data  
processing method in which high quality images can be  
formed on a recording material with suppressed banding  
nonuniformly, more particularly to the ink jet  
10   recording method, the recording device and the data  
processing method in which the recording is carried  
out through one-path or multi-path printing.

          The present invention is applicable to any  
equipment using as the recording material, paper,  
15   textile, leather, nonwoven fabric, OHP sheet, metal or  
the like. More particularly, the present invention is  
applicable to a printer, copying machine, facsimile  
machine or another office equipment, industrial  
manufacturing machines or the like.

20           As regards the recording on the recording  
material using the recording apparatus, the demand for  
high-speed printing picks up. In order to increase  
the printing speed, it is one of the methods to refuse  
the number of paths in the multi-path printing which  
25   has been proposed to accomplish formations of high  
quality images. Here, the number of paths is the  
number of scans of the carriage required to complete

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one line of printing.

Since the number of ejection outlets of the recording head is limited, the amount of the sheet feed for units can be smaller if the number of paths is larger. On the other hand, the sheet feeding distance per unit can be increased by reducing the number of paths. For example, in the case that printing is carried out in the two-path mode, the speed can simply be doubled by changing it to one-path printing. That is, the reduction of the number of paths reduces the number of scans to cover a predetermined area (one sheet, for example), and increases the distance of sheet feed, so that time required for printing is shortened.

In the case that recording is carried out having a plurality of ejection outlets for ejecting the recording liquid (ink) scans the recording material in the direction perpendicular to the direction in which ejection outlets are arranged, an image is formed in an image area in the form of a band by one scan of the recording head, as shown in Figure 21.

Thus, in the case of the one-path printing, the duty (ratio) of the recording ink ejected per unit time is larger than when the one band area is printed through a plurality of scans (multi-path printing). Therefore, the production of the black stripe between the adjacent bands (paths) is remarkable at the

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portions where the printing duty is high, although it is different depending on the nature of the recording material and the recording liquid.

5 The problem is more significant in the case of lateral arrangement of the recording heads in which cyan, magenta and yellow recording heads or the like are arranged in the main scan direction. This is because the boundaries appear at the same position. Figure 6 schematically shows the laterally arranged  
10 recording heads.

The black stripe appearing at the adjacent bands is called connecting stripe, spending or the like. It might deteriorate the image to such an extent that image is practically unsatisfactory.  
15 ~~Sub A)~~ Therefore, a method of avoiding the banding in one-path printing, thus improving the image quality.

For example, Japanese Laid-open Patent Application 11-188898 discloses a serial scanning type  
20 in which a recording head repeatedly scans the recording material in the main scan direction to print the image band by band, a method is used to avoid the production of a stripe at the connecting portion between the adjacent bands. More particularly, at  
25 least one of the first and the last raster lines of one band covered by one scan of the recording head is divided into a plurality of unit areas including a

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predetermined number of dots. In accordance with the image data, more particularly, with a sum of an amount of ink ejection for a noting color in each of the divided areas and an amount of ink ejections for the other in the unit areas, the amount of the ink actually ejected is reduced (thinning).

However, in the conventional method, the accuracy of the suppression of the banding in the case of plain paper or the like with which the banding tends to occur.

#### SUMMARY OF THE INVENTION:

Accordingly, it is a principal object of the present invention to provide an ink jet recording apparatus, a recording method and a data processing method with which the banding is suppressed even in the case of one-path printing.

According to an aspect of the present invention there is provided an ink jet recording apparatus for effecting recording on a recording material by ejecting ink with relative scanning movement between a recording head and the recording material, said ink jet recording apparatus, comprising:

obtaining means for obtaining information indicative of an amount of ink to be ejected to each of unit areas provided by dividing an area in the

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neighborhood of a boundary between adjacent bands of scanning recording of said recording head on the recording material; and

control means for controlling an amount of being to be ejected to the unit area on the basis of the output of said obtaining means,

wherein the unit areas exist astride the boundary between adjacent one of the bands.

According to another aspect of the present invention there is provided an ink jet recording apparatus for effecting recording on a recording material by ejecting ink using a recording head having a plurality of recording elements, said ink jet recording apparatus comprising:

recording scanning means for effecting recording with relative scanning movement between the recording head and the recording material in a main scan direction;

subscanning means for imparting relative scanning movement between the recording material and the recording head in a direction which is different from the main scan direction substantially each time after completion of recording scan in the main scan direction;

dot count means for counting ink ejection data number for each of unit areas provided by dividing an area in the neighborhood of a boundary

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between adjacent bands of scanning recording of said recording head on the recording material;

determining means for determining a thinning rate for each of the unit areas on the basis of an  
5 output of said dot count means; and

thinning means for effecting a thinning process to the ink ejection data on the basis of the thinning rate determined by determining means,

wherein the unit areas exist astride the  
10 boundary between adjacent one of the bands.

According to a further aspect of the present invention there is provided an ink jet recording apparatus for effecting recording on a recording material with relative scanning movement between a  
15 recording head and the recording material, said ink jet recording apparatus comprising:

obtaining means for obtaining information indicative of an amount of ink to be ejected to each of unit areas provided by dividing an area in the  
20 neighborhood of a boundary between adjacent bands of scanning recording of said recording head on the recording material; and

control means for controlling an amount of the ink ejected to an area to be thinned in the unit  
25 area on the basis of an output of said obtaining means;

wherein the inks of the unit area and the

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area to be thinned are different from each other.

According to a further aspect of the present invention there is provided an ink jet recording apparatus for effecting recording by ejecting ink onto  
5 a recording material on the basis of data using a recording head for ejecting the ink through a plurality of nozzles, said ink jet recording apparatus comprising:

recording control means for imparting  
10 relative movement between said recording head and the recording material and rejecting thing from said recording head in accordance with ink ejection image data to sequentially effecting recording operations for adjacent recording areas by the ink ejected from  
15 the recording head; and

correcting means for counting data indicative of ejection of the ink for boundary areas of adjacent recording areas and reducing the ejection data for the boundary areas.

20 According to a further aspect of the present invention there is provided a method of correcting image data for an ink jet recording apparatus for effecting recording by ejecting ink onto a recording material on the basis of data using a recording head  
25 for ejecting the ink through a plurality of nozzles, said apparatus imparting relative movement between said recording head and the recording material and

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rejecting thing from said recording head in accordance with ink ejection image data to sequentially effecting recording operations for adjacent recording areas by the ink ejected from the recording head, the

5 improvement residing in:

a step of correcting the ink ejection data by counting data indicative of ejection of the ink for boundary areas of adjacent recording areas and reducing the ejection data for the boundary areas.

10 According to the present invention, the unit areas as a whole are astride the adjacent bands, the behavior of the ink in the boundary therebetween can be properly analyzed.

15 By using different sizes for the dot count area and the thinning area, appropriate thinning is possible.

20 These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS:

25 Figure 1 is a partly broken perspective view of an ink jet recording apparatus according to an embodiment of the present invention.

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Figure 2 is a schematic perspective view of a major part of a recording head used in the apparatus of Figure 1.

Figure 3 is a block diagram of a control  
5 circuit for an ink jet printing apparatus according to an embodiment of the present invention.

Figure 4 is a flow chart of process steps according to a first embodiment of the present invention.

10 Figures 5A and 5B illustrate an area for which a dot counting operation of the print data is carried out and an area in which the thinning is executed.

Figure 6 is a schematic view illustrating a  
15 structure of the recording head according to the first embodiment of the present invention.

Figure 7 is a flow chart of color area discrimination steps according to the first embodiment of the present invention.

20 Figure 8 is a schematic illustration of an example of a dot count in a unit area according to the first embodiment of the present invention.

Figure 9 shows an example of the sections of the color areas according to the first embodiment of  
25 the present invention.

Figures 10A and 10B show an example of a thinning rank graph according to the first embodiment

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of the present invention.

Figure 11 shows an example of the count in a SMS process according to the first embodiment of the present invention.

5            Figures 12A to F show an example of a thinning rank graph according to the first embodiment of the present invention.

10           Figures 13A and B illustrate a mechanism of ink bleeding occurring at the connection between adjacent bands.

            Figures 14A-D illustrate a print data processing using the SMS process according to the first embodiment of the present invention.

15           Figures 15A-F illustrate a print data processing using the SMS process according to the first embodiment of the present invention.

Sub A2)       Figures 16A-C are schematically illustration of a recording head according to a second embodiment of the present invention.

20           Figure 17 shows an example of the sections of the color areas according to the second embodiment of the present invention.

25           Figures 18A and B illustrate an example of a dividing method in a color area according to the second embodiment of the present invention.

            Figures 19A to F show an example of a thinning rank graph according to the second embodiment

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of the present invention.

Figures 20A to F show an example of a thinning rank graph according to the second embodiment of the present invention.

5 Figure 21 is a schematic view illustrating a band and boundary.

Figures 22A-E illustrate a thinning process using a mask according to an embodiment of the present invention.

10 Figures 23A and 23B are schematic illustrations of behavior of the recording ink on the recording material.

Figure 24 is a flow chart of thinning process at the boundary between the adjacent bands according to the second embodiment of the present invention.  
15 Figure 25 is a schematic illustration of a Table to be used in the thinning process.

Figure 26 is an illustration of a thinning process for the image data in a buffer.

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#### DESCRIPTION OF THE PREFERRED EMBODIMENTS:

The preferred embodiments of the present invention will be described taking a serial printer having a plurality of recording heads for instance.

25 In this embodiment of the present invention, a neighborhood of a connecting or boundary portion of the data of one band is divided into a plurality of

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unit areas, and the number of dots for each of the unit areas are counted, and then, the color area of a noted area is discriminated on the basis of the dot counts for the respective colors. A thinning rank for each thinning process area is determined for each color on the basis of a predetermined thinning rank graph and a dot count (or printing duty) for each unit area provided by a sum of the dot counts for each color in the color area.

10 This will be further described.

(Position of thinning process)

As shown in Figures 5A, B, the area in which the thinning process is executed is several raster areas (4 rasters, for example) at a sheet inlet side (upstream side with respect to the feeding direction of the sheet) in one scan area to be printed. It is noted that thinning beforehand, that is, the thinning in the sheet feeding side is preferable than the other, since the margin relative to the recording material is large. By doing so, a larger number of recording materials can be supported than in the case that thinning processes effected at the sheet discharging side on the basis of one parameter.

When the thinning process is effected over several raster areas, the degrees (rank graph, in this example) of thinning can be independently selected for each raster areas or for each several raster areas, by

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which, for example, the degree of thinning can be made higher in the area closer to the boundary than in the other areas, thus improving the accuracy of the thinning process.

5 (Dot count area)

The area in which the dots are counted, as shown in Figure 5A, is 16 dot x 16 raster areas (dot) astride the boundary area. Since the area in which the dots are counted is larger than the thinning area so that print data of the bands astride the boundary are counted, the circumstances influential to the bleeding at the boundary can be taken into consideration.

(Thinning processing method)

15 The thinning process for the print data in this embodiment is a so-called SMS (sequential multi-scan) type. Other thinning processing methods include a type using a pattern mask and an error diffusion (ED) type.

20 However, in the method using the pattern mask (Figure 22A-E), a mask of staggered arrangement is used for example (pixel data of white parts are skipped), and when the print data having the same amounts of ink ejections as shown in Figure 22B. C, 25 are processed, the data after the process are shown in Figures 22D and 22E, and the print data at the "x" portions are skipped. As will be understood from the

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two Figures, the thinning mask and the print data  
interfere in the case of the data of the same ejection  
amount (duty), depending on the arrangement of the  
print data, and therefore, the amount of thinning  
5 cannot be controlled in some cases.

As to the use of the error diffusion type,  
the following is an example.

If the pixel for which the quantitized image  
data process is to be effected, contains the data to  
10 be printed, a multi-level value is assigned in  
accordance with a predetermined nozzle correction  
value:

Errors of the peripheral pixels are added:

After comparison with a predetermined  
15 threshold, it is determined whether or not the print  
data is skipped or not:

The error resulting from the determination is  
calculated.

The error is assigned to a peripheral pixel  
20 or pixels: and

If the pixel for which the quantitized image  
data process is to be effected, does not contain, the  
errors in the peripheral areas are obtained and then  
are reassigned to the peripheral areas.

25 It is predicted that in the case of 1 path  
printing, the print data process requires too long  
time, since the recent high density nozzle head has

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many nozzles. If the printing operation is interrupted waiting for the data processing, the carriage has to stop with the result of low throughput which is against the purpose of use of one-path printing.

In view of this, in this embodiment, the use is made with a so-called SMS thinning process to accomplish both of the uniformation of the amount of thinning and the high speed processing. In the SMS thinning process, whenever there is a printing datum, the count designated by the counter (register) (particular bit; MSB, for example), and if it is "1", the print data is not skipped (printed), and on the other hand, if the counter value is "0", the print data is skipped (thinned) (not printed). The counter is shifted to the right (bit shift). When the counter is shifted to the right side end, it returns to the left end (cyclic shifting).

This is repeated for each of the print data to determine the dots to be skipped. As described in the foregoing, the determination whether the thinning is to be detected, is carried out only for the dots having the print data, and therefore synchronism with the pattern of the print data does not occur.

(Thinning table)

The coloring at a marginal area of printed dot is different if the order of prints of inks on the

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recording material is different. Figures 23A, B schematically show an example of penetration of the recording ink into the recording material. The behavior of penetration of the recording ink is  
5 different depending on the material of the recording ink, the recording material, the ambient conditions, differences in the time interval between prints or the like, though.

Here, the later printed recording ink 232  
10 sink under the first printed recording ink 231. In this manner, the recording inks printed onto the same position on the recording material do not mix with each other, usually, and the coloring occurs with the situation shown in Figure 23A. It will be understood  
15 that at the end 233 of the printing indicated by a circle in Figure 23B, has a coloring which is different from that inside 234 in the inside. More particularly, the later printed ink has a stronger coloring than the first printed ink. This functions  
20 also to worsen the connecting seam at the boundary. Therefore, even if the same thinning rate is used for the recording ink to be first printed and the recording ink to be later printed, the differences in the coloring at the marginal area are not avoided.  
25 Therefore, in this embodiment, the thinning rate is determined in consideration of the order of depositions of the ink onto the recording material.

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Figure 10A shows an example of a rank graph for a thinning to be used for determining the thinning rate in this embodiment. The thinning rank graph gives ranks corresponding to the dot counts in the dot count area for each of the inks which is subjected to the thinning process.

The thinning rank graph is designated on the basis of three values, namely, a start dot number, the dot interval and the MAX rank. The levels of the thinning ranks are determined beforehand. In this embodiment, for example, there are nine levels, namely, 0%, 12.5%, 25%, 37.5%, 50%, 62.5%, 75%, 87.5% and 100%.

Sub A3) The respective parameters will be described. The start dot number is the total dot count at which the use of the thinning rate 12.5% (thinning rank 1) is started. The dot interval is the dot count before the next thinning rate (25% if the current thinning rate is 12.5%), that is, the range of the dot count using the same thinning rate. MAX rank is the maximum thinning rate, that is, no thinning rate beyond that is not selectable. If the thinning rate reaches the MAX rank, the thinning rate is not raised, and the MAX rank thinning rate is maintained even if the dot count reaches the number corresponding to the dot interval.

Because of this system using the three parameters, one thinning line in the rank graph can be

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expressed by 1 bite ((8 bits); one component (8 levels) for the start dot number, one component for the duct interval (8 levels), and one component (4 levels) for the MAX rank 1.

5 <sup>Sub</sup> A5) In order to enhance the resolving power for each of the parameter, the number of bits may be increased. Alternatively, the number of bits is not changed, but a common offset value may be given commonly to the start dot number, the dot interval and  
10 the MAX rank, by which the parameters can be more accurately set.

In this manner, the amount of the data required for setting the thinning rank graph. The reduction of the amount of the data is particularly  
15 preferable in this embodiment. The reason is as follows. In order to carry out the connecting processing as in this embodiment in the quick printing mode as in the one-path printing mode, use of hardware prefers to the use of software. This is because the  
20 speed of the data processing using the software is not enough to catch up with the printing speed. It is preferable to use hardware such as a gate array. In this case, the number of required data is directly influential to the number of gates, and therefore,  
25 less number of data is preferable from the standpoint of the circuit scale.

Figure 10B shows another example of the

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thinning rank. This example is particularly effective in such a case that inclination of the thinning rank line is desirably changed.

5 In addition to the three parameters required to express the thinning ranks, there are provided the change dot number indicative of the start point of the inclination change and the dot interval 2 for determining the new inclination, in this example. With use of such parameters, more accurate control is  
10 accomplished.

(Color area discrimination)

Depending on the relationship between the used ink and the recording material, the behavior on the recording material after the actual printing is  
15 different, and the conspicuousness of the boundary line and the effectiveness to the boundary line after the thinning process is also different.

For example, in the case of a gradation from white to blue and UC (under color, mixture of YMC),  
20 the printing is carried out using the cyan ink and the magenta ink where the color is changing toward blue, and at the position where the blue reaches the maximum level, the solid printing occurs for the cyan and magenta colors (the data of maximum duty). In the  
25 state, in order to reduce or suppress the boundary line, a certain high degree of thinning process is effected to the cyan and magenta colors.

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Suppose that gradation from white to red and UC using the same thinning parameters. Then, the cyan ink is first started to be used at the point of change from the red at the maximum to the UC. At this point, the data for the magenta have the maximum duty level which is the same as the position where the gradation changes from the blue to the black in the foregoing white - blue - black gradation example, and therefore, the highly thinning rate used for the cyan and magenta colors in the foregoing example, is used in this example. These results in that large percentage of cyan dots are removed in the area where the cyan dots are sparse, and therefore, lack of cyan dots is conspicuous.

Thus, it is desirable in the connecting process in the boundary area in the formation of color images that in addition to the conventionally used total amount of the ink to be applied to the unit area adjacent to the end portion, the information relating to the hue and the chromaticity of the unit area and the information as to which recording ink is used for printing is obtained, and that thinning rate is selectable on the basis of these pieces of information. In order to accomplish this, in this embodiment, the discrimination is made as to the hue and the chromaticity of the noting area (unit area) from the dot count for each color. In the following,

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the term color area is used as a word covering both of the hue and the chromaticity in combination.

In the foregoing embodiment, the color area of the noting area is discriminated from the number of recording data (the number of dots to be printed) in the neighborhood of the boundary area between adjacent bands, and in accordance with the color area, the thinning rank (the degree of thinning) can be selected for each of the used ink and the recording positions. Using the selected thinning rank, the thinning process is effected to each of the inks, so that conspicuousness of the boundary line between adjacent bands can be suppressed in the one-path printing.

The description will be made as to Details of this embodiment. The same reference numerals are assigned to the elements having the corresponding functions in the Figures.

(First embodiment)

The first embodiment creates to a recording system in which the plurality of recording heads are used to effect recording on the recording material with recording ink.

(Example of recording device structure)

Figure 1 is a schematic perspective view of a major part of an ink jet recording apparatus according to the first embodiment of the present invention. In Figure 1, a plurality of (3, in this embodiment) head

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cartridges 1A, 1B, 1C are replaceably mounted on the carriage 2. Each of the cartridges 1A-1C is provided with connector for receiving a signal for driving the recording head. In the following descriptions, when  
5 all the recording means 1A-1C or anyone on them are designated, the term "recording means" (recording head or head cartridge) is used.

The respective cartridges 1 function to print different color inks. Therefore, the ink containers  
10 contain cyan, magenta, yellow inks and so on which have different colors. Each of the recording means 1 is exchangeably positioned and carried on the carriage 2 the carriage 2 is provided with a connector holder (electrical connecting portion) for transmission the  
15 driving signal or the like to each of the recording means 1 through the connector.

The carriage 2 is supported and guided on a guiding shaft 3 extending in the main scan direction in the main assembly of the apparatus, and is movable  
20 in the main scanning direction. The carriage 2 is driven and controlled by the main-scanning motor 4 through a motor pulley 5, a driven pulley 6 and a timing belt 7. The recording material 8 such as a sheet of paper, thin plastic resin sheet or the like  
25 is fed through a recording position where the recording material is faced to the ejection outlet side surface of the recording head 1 by the rotation

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of the two pairs of feeding rollers. The recording material 8 is supported on a platen (unshown) at the back side so as to provide a flat recording surface in the recording position. In this case, each of the cartridges 1 carried on the carriage 2 has the ejection outlet side surface which is projected downwardly from the carriage 2, and is supported to be parallel with the recording material 8 between the pairs of feeding rollers.

The recording head 1 is in the form of an ink jet recording means which ejects the ink using the thermal energy, and is provided with electrothermal transducers for generating thermal energy. In the recording head 1, film boiling is caused by the thermal energy applied by the electrothermal transducer. By the growth and collapse of the bubble created by the film boiling, a pressured change is produced so as to eject the ink. Figure 6 illustrates a structure of nozzles of the recording heads.

Figure 2 is a schematic perspective view illustrating a major part of an ink ejection portion 13 of the recording head 1. As shown in Figure 2, the ejection side surface 21 is faced to the recording material 8 with a gap of approx. 0.5-2 mm, and is provided with a plurality of (256 in this embodiment) ejection outlets 22 at a predetermined intervals (360dpi in this embodiment). The recording head

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further includes a common liquid chamber 23 and flow paths 24 for fluid communication between the common liquid chamber 23 and the ejection outlets 22. Each of the flow paths 24 is provided of the wall constituting the path with an electrothermal transducer 25 (heat generating resistor, for example) which is effected to generate energy corresponding to the amount of the ink ejection. In this embodiment, the recording heads 1 are carried on the carriage 2 in the manner that said ejection outlets 22 are arranged in the direction crossing with the scanning direction of the carriage 2. The electrothermal transducers 25 corresponding to the image signals or to the ejection signals are actuated (energized) to cause a film boiling in the ink in the flow path 24, and the pressure produced by the boiling functions to eject the ink through the ejection outlet 22.

Figure 3 schematically illustrates a control circuit used in the ink jet printing apparatus shown in Figure 1.

sup AS) In Figure 3, a controller 100 constitutes a main controller and includes a CPU101 in the form of a microcomputer, a ROM 103 storing a program, a table, fixed data or the like, and a RAM 105 providing an area for conversion of the image data and a working area. The host apparatus 110 is the supply source of the image data, and it may be a computer which



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cont.) produces and processes image data or the like relating  
to the printing, or it may be a reader portion for  
reading images. The image data, the command, the  
status signal and the like are supplied to or receive  
5 from the controller 100 through an interface (I/F).

An operating portion 120 include a group of  
switches operable by the operator, a main switch 122,  
a print start switch 124, a recovery switch 126 for  
actuating suction recovery operation.

10 A head driver 140 actuates the ejection  
heaters 25 of the print head 1 in accordance with the  
print data or the like. The head driver 140 includes  
a shift register for aligning the print data  
corresponding to the positions of the ejection heater  
15 25, a latching circuit for effecting latching at  
proper timing, a logic circuit element for actuating  
the ejection heater in synchronism with the drive  
timing signal, a timing setting portion for properly  
setting the actuation timing for correct positioning  
20 of the dot formation.

The print head 1 is provided with a sub-  
heater 142. The sub-heater 142 functions to control  
the temperature in order to stabilize the ejection  
property of the ink, it may be formed on the print  
25 head substrate simultaneously with the ejection heater  
25, or it may be mounted to the main assembly of the  
print head or the head cartridge.

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The motor is to drive the main-scanning motor 152, and the sub-scan motor 162 is for feeding the print medium 8 (sub-scan), the motor driver 150 is a driver for the motor.

5 (Print data process)

Figure 4 is a flow chart showing operations from the reception of the amount of the print data corresponding to one scan to the end of the print data process.

10 At step S1, the amount of the print data required for printing one scan for each of the different color inks. For the printing of one scan, the data for one band is necessary, and the data in the dot count area of the next band are required as well. Here, one band is a printing area printed by one carriage scanning operation.

15 After the print data is received, a step S2 executes the dot count operation, a step S3 executes the color area discrimination, a step S4 executes the thinning rank determining operation, and a step S5 effects the SMS thinning process, for each of the unit areas, that is, each of 16 dots x 16 dots raster areas shown in Figure 5. At step S6, the foregoing process is repeated until one band is covered. The description will be made as to the respective processes.

25 (Dot count)

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In this embodiment, the area subjected to the dot count operation is a width corresponding to the 16 raster lines including the connecting portions between adjacent bands.

5           The dot count operation is carried out for all of the recording inks carried on the recording device of this embodiment, more particularly, the dot count operation is carried out for the binary data for the cyan, magenta and yellow colors. A sum of the dot counts of them is the dot count (or the total dot count) as a result of the dot count operation.

10           Here, the event that dot count is "1" means that one dot is present in one pixel, and the event that dot count is "2" means that two dots are present in one pixel.

15           The dot count operation is carried out in the divided areas adjacent to the boundary between adjacent bands, and the size of the area is 16 raster lines in the sheet discharging direction, and 16 dots in the scanning direction of the carriage (unit area for the dot count). . Therefore, the maximum of the total dot count value is 16 (raster) x 16 (dots) x 3 (color number) = 768.

20           In the process of this embodiment, and the thinning rank is determined from the total dot count obtained by the dot count step, and the SMS thinning process is carried out. It is possible to obtain

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relative information indicative of the relative relation among the amounts of the inks printed in the unit areas, from the dot counts for each of the colors, and the discrimination is made as to the color area (hue and chromaticity) of the unit area from the relative information.

Such a process is repeated for one band until all of the bands corresponding to one page are subjected to the process, so that print data are generated.

Therefore, in the case of 360dpi A4 full scanning (8in. ), 180 calculations ( $360 \text{ (dpi)} \times 8 \text{ (inch)} / 16 = 180$ ) are to be carried out.

In this embodiment, the total dot count is the simple total sum of the dot counts of the cyan, magenta and yellow colors, but the counts may be weighted depending on the colors when the degrees of influence to the production of the boundary strike are not uniform. For example, in a case, the conspicuousness of the boundary line is worsened by the yellow ink, then, the dot count for the yellow color may be weighted, for example, the dot count of the yellow is multiplied by 1.2. In another case, the ejection amounts are different depending on colors (for example, in the amount of the ejected red ink is larger than the other, then, this is taken into account.

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Using the dot count process as described in the foregoing, the data processing may be carried out only for the small areas which is adjacent to the boundary between bands (that is, the end portion of the array of the nozzles. Therefore, the load  
5 required by the process is small, such that even in the case that time period which can be given to the process is short as in the case of one path printing.

The description will be made as to the reason  
10 why the 16 dots x 16 dots area astride the boundary between the adjacent bands is selected as the unit area in which the dot count operation is carried out.

In this case, the maximum value of the total dot counts is  $16 \times 16 \times 3$  (the number of colors) = 768.  
15 In order to form 1 band, 180 calculations are required in the case of 360dpi, as described hereinbefore, and in the case of 600dpi, A4 full scanning (approx. 8in.), the number of calculations is  $600 \text{ (dpi)} \times 8 \text{ (inch)} / 16 = 300$ . More specifically, as shown in Figure 5A,  
20 the dot count operation is sequentially carried out for each of the dot count unit areas for all of the range determined by the set length, and the calculations are carried out for all of the dot count unit areas, by which the dot count operation for 1  
25 band is completed.

By using the areas astride the boundary between the adjacent bands in this manner, the state

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of print dots before and after the boundary can be known. More particularly, it is possible to discriminate whether or not the ink ejections tend to produce the boundary line, and therefore, a high precision boundary processing is accomplished. When the dot count operation is carried out only for the areas within one band, it is possible to predict the degree of ink bleeding attributable for the production of stripes within the band, but it is not possible to predict the degree of influence to the next band. The production of the boundary line or stripe is dependent on the amount of the ink adjacent the boundary between the adjacent bands.

For example, when a certain quantity of ink is in the next band, the boundaries stripe is suppressed due to the ink bleeding. When the amount of the ink is small, the possibility of the production of the stripe is not high, although the ink bleeding may occur.

Referring to Figures 13A, B, the description will be made as to the mechanism of the stripe production.

To the place where the shot ink is being fixed with some bleeding, the next band ink is shot. Then, in the process of the next ink penetrating into the material of the sheet or on the surface thereof, the next ink is considered as being attracted to the

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ink of the previous shot. At this time, if no processing is given to the boundary area, the amount of the ink at the boundary becomes larger, is shown in Figure 13A with the result of a darker boundary. This is considered as the cause of the production of the stripe.

In order to avoid this, the boundary processing is carried out as shown in Figure 13B to reduce the amount of the ink either in the first or second band, that is, the print data are thinned. The thinning process may be carried out in one of the first and second bands or in both of them.

As described in the foregoing, the production of boundary stripe is attributable to the amounts of the ink in the adjacent bands. Therefore, the selection of the areas to be processed extend astride the boundary is effective for the processing.

At the time of the dot count operation, the data for the first band or the second band may be weighted. For example, when the cause of the stripe production is the amount of the ink, the dot count of the first shot band may be multiplied by 1.2, so that amount of the ink in the first band may be sensitively taken into account.

(Color area discrimination)

Figure 7 is a flow chart for the color area selection.

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At step S2, the dot count operations are carried out for the respective colors. Figure 8 shows an example of dot count in a unit area, and Figure 9 shows sections of color areas used in this embodiment.

5 In example of Figure 8, the order of the number of dots is the magenta, the cyan and the yellow (smallest). The portion of yellow with which the dot count is the minimum among the three colors is called "UC" (under color), the portion resulting from the  
10 cyan (second largest) deducted by the UC is the secondary color (D2, blue in this embodiment) portion. The portion of the magenta (the largest) detected by the second largest cyan is the primary color (D1, magenta in this embodiment). . The D1, D2, UC are  
15 calculated in a step S31.

Sub A2  
20 The largest among the D1, D2, UC is discriminated, by which the position of the noting dot count area (unit area) in Figure 9 is determined (step S32). In this example, D1 is the largest, and therefore, it is discriminated that dot count area is in the cyan.

If there are two or three largest number portions in the D1, D2, UC, the color area is selected in the order of UC, D2, D1 (if UC and D2 are the same, UC, is selected; if D1 and D2 are the same, D2 is  
25 selected, and therefore, D1 is not used actually). . (Thinning rank graph)

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Figure 10A shows an example of a rank graph for determining the thinning rank.

Here, Figure 10A is plots of the total dot count (ordinates) vs. the thinning rank corresponding to the thinning rate (abscissas). Using the graph, the thinning rate for the data (count in the SMS processing) is designated on the basis of the total dot count for the unit area, obtained by the dot count process.

In these embodiments, the thinning rates are one of 0%, 12.5%, 25%, 37.5%, 50%, 62.5%, 75%, 87.5%, 100% (nine levels). The counter value is shown in Figure 11.

As described in the foregoing, the designation of the thinning rank graph is determined on the basis of the number of the start dot, the dot clearance and the MAX rank.

Figure 10A also shows the correspondence of the three parameters and the thinning rank graph.

In this embodiment, as described in the foregoing, in the three parameters are the start dot number, the thinning clearance and the MAX rank, in accordance with which the thinning rank graph is selected. However, this way of selection is not limiting in the present invention. In view of the fact that with the foregoing method of determination of the thinning rank graph, the relation between the

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total dot count number and the thinning rate cannot be other than linear, another method is such that thinning rank graph per se is speculated.

The number of levels of the thinning rates is  
5 not necessarily limited to nine, but may be increased as desired.

Figure 12 shows an example of the thinning rank graph used in this embodiment. As described in the foregoing, the thinning rank graph is determined  
10 properly for each color, and Figures 12A-F show an example for one color area (cyan).

In this embodiment, the thinning rank is designated for each of different inks (cyan, magenta and yellow). The thinning area is divided into two  
15 portions in the sheet discharge direction (sub-scan direction), and the thinning rank graphs are selected independently from each other. Therefore, in Figures 12A-F, six thinning rank graphs are used (cyan upper, cyan lower, magenta upper, magenta lower, yellow upper  
20 and yellow lower).

In addition, Figures 12A-F show only the graphs for the color areas (cyan in this example) discriminated as a result of color area discriminating operation. Actually however, such a combination is  
25 present in each of the magenta, the yellow and the UC.

By setting the thinning rank graph for each of different inks, the control can be responsive to

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the difference in the degree of the boundary stripe  
due to the difference in the behavior on the recording  
material depending on the inks, the difference in the  
conspicuousness due to the difference in the lightness  
5 and/or the chromaticity depending on the inks.

Additionally, the thinning rank graph can be  
set for each color, and the process can be responsive  
to the change in the color at the end portion  
resulting from the order of shots onto the recording  
10 material. The change in the color at the end portion  
is like this. As described referring to Figures 23A,  
B, the behavior of the ink is dependent on the time  
difference of the ink ejections onto the recording  
material and on the property of the recording  
15 material, but in the case that time difference of the  
objections is very short because of the lateral  
arrangement of the recording heads, an outline  
bordering of magenta color is produced when the cyan  
and magenta inks are shot at the same position on  
20 plain paper, for example. In such a case, that is,  
the outline color change occurs, the changing of the  
thinning pressure is effective. More specifically, in  
the case of the shots in the order of cyan ink and  
magenta ink, the thinning ratio for the magenta is  
25 made higher than that for the cyan, by which the  
boundary stripe can be suppressed more.

(Thinning process area)

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In this embodiment, as has been described in the foregoing referring to Figure 5A, the data of 4 raster areas at the sheet feeding side in one band are processed, and therefore, the data in the area of 16 dots in the main scan direction are processed. Furthermore, as shown in Figure 5A, the 4 raster area is divided into 2 raster areas at the sheet discharge side (upper) and 2 raster areas at the sheet feeding side (lower). For each of the defined in the areas, the thinning rank can be selected, that is, different thinning rank graphs are prepared.

As will be understood from Figure 5A, the thinning area and the dot count area used in this embodiment are not the same area, but only a part of the dot count area is the thinning area. It is not necessary that thinning area and the dot count area are the same.

This is because the causes of the production of the boundary stripe is not so simple that problem may be solved by the boundary per se, but it is considered that ink bleeding between the bands and the ink bleeding away from the portion by several raster lines propagates through chain reaction depending on the connections of the dots. For example, the boundary stripes are different between when the ink is ejected only for 4 raster lines at up to the boundary and when the ink is ejected for 8 raster lines. More

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particularly, the stripe is more remarkable in the latter. Because the ink bleeding occurring at the position several rasters away from the boundary gradually propagates with the result of the amount of the ink at the boundary is relatively large, and therefore, the boundary stripe is relatively remarkable. Therefore, it is desirable that dot count area is larger than the thinning area and is determined in consideration of the chain reaction propagation of the ink bleeding. In this embodiment, the dot count area twice as large as the thinning area.

As regards the size of the thinning area, it is desirable that it has a certain area from the standpoint of effectiveness of the processing. If, however, it is too large, the density may become too low due to the thinning process with the possible result of white stripe. In view of these factors and properties of thing, proper width of the thinning area is determined. In this embodiment, the thinning area has a width corresponding to the 4 raster areas (0.17mm in the case of 600dpi). This is effective to suppress the boundary stripe without inducing the white stripe.

In these embodiments, 4 raster lines are used for the thinning process area, and the area is divided into two parts. This is not limiting, and it may be

By the further deviation of the thinning area and the independent assignment of the thinning table for each of the divided areas, proper thinning rates and the thinning areas can be selected depending on the degrees of the boundary stripes.

In view of this, the thinning ranks are  
25 determined for the respective raster lines. In  
addition, the thinning ranks are determined in  
accordance with the distance from the boundary, by

In view of this, the thinning ranks are  
25 determined for the respective raster lines. In  
addition, the thinning ranks are determined in  
accordance with the distance from the boundary, by

which the accuracy of the processing is improved.  
(SMS thinning process)

In the SMS thinning process, the designated  
count (specified bit, for example, MSB in this  
5 embodiment) is read by the counter (register) each  
time the print data is supplied, if it is "1", the  
print datum is printed, and then the counter is  
shifted rightward by "1". If the counter "0", the  
print data is thinned, and then the counter is shifted  
10 rightward by "1". When the counter reaches the  
rightmost position, it is returned to the leftmost  
position. The process is repeated each time the print  
data is supplied, thus determining the dots to be  
skipped.

15 Referring to Figures 14A-D and Figures 15A-F,  
the SMS thinning process will be described. In these  
figures, the print data are indicated by "o", and no  
print datum is indicated by "x". The noting datum is  
indicated by bolding. As regards the counter value,  
20 the portion to be printed is indicated by "1", and the  
portion to be skipped is indicated by "0", and the  
column designated by the counter is indicated by  
bolding.

In Figure 14A, the first print datum is "o",  
25 and the count is 0, and therefore, the first data is  
skipped or removed. Therefore, the first print datum  
after the processing is "x", and the counter shifts by

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one to the right (Figure 14B). The next datum is not indicative of printing, and is maintained "x", and the counter does not shift and is retained there (Figure 14C). The third print data has the counter value of "1", and the print datum remains, and the counter is shifted by one to the right. In this manner, the print data are skipped at the ratio of 1 out of 4 (Figure 14D).

Figure 15A-F shows an example of the data before and after the thinning process in which the thinning process is effected in the area defined by 8 dots in the main scan direction and 4 raster lines in the sheet discharge direction (one half in the main scan direction) since the thinning process area is constituted by 4 raster lines, in this example, the thinning ranks are "2" at the sheet discharge and "4" at the sheet feeding side, respectively.

For the best understanding, the raster lines are called "first raster", "second raster", "third raster", "fourth raster" from the sheet discharge side in Figure 15A.

The SMS thinning process is carried out from the sheet discharge side raster for each of the rasters. After the processing for one raster, the next raster is processed. The SMS counter does not return to the initial position even if the thinning level is changed. The SMS counter does not return to

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the initial position even if the thinning process area is shifted to the adjacent area within the same band, and the counter position is retained in one band.

When the operations shifted into a different band, the counter position is returned to the initial position.

The initial position in the first process area in one band is randomly designated. As a result, the processing from the first raster to the fourth raster is as shown in Figure 15B, and it is as shown in Figure 15F as a whole.

According to this embodiment of the control method, the color area of the noting area is discriminated from the number (the number of dots to be printed) of the recording data neighborhood the boundary, and in accordance with the color area, the thinning rank can be selected for each of the inks used. By effecting the thinning process for each of the inks in accordance with the set thinning rank, the degree of production of the boundary stripe in one-path printing can be suppressed.

(Second embodiment)

The second embodiment of the present invention is similar to the first embodiment in that printing is effected with the recording ink onto the recording material using a plurality of recording heads.

The structure of the recording device used in

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this embodiment, the thinning process area and the SMS thinning process in this embodiment are the same as those in the first embodiment.

(Dot count)

5                   In this embodiment, the dot count unit area is the same as with the embodiment.

Figure 16A shows a head structure used in this embodiment.

10                   With this structure, the number of nozzles for ejecting the black ink is not less than twice as many as the number of color nozzles, so that when the data contain only black data, the black nozzles are fully used to raise the printing speed. In the case of the mixture of black and chromatic data, the number of black nozzles to be actuated is reduced in order to suppress the bleeding among the black dots, and in the case of the black and color printing, at least one scan black is given. Figure 16B schematically shows the printing of black data only, and Figure 16C

15

20                   schematically shows the printing of black and chromatic data in mixture.

25                   The boundary stripe tends to occur in the case of the color printing since the amount of the ink is large on the recording material. In this case, the black printing is carried out prior to the color printing with the nozzles structure in this embodiment. Therefore, at the time of the color

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printing, the black ink printing has already finished, and the black ink has started fixing on the recording material. For this reason, the black ink is not influential to the boundary stripe.

5           In this embodiment, the dot count is not carried out for the black ink, accordingly. But, the color inks (cyan, magenta and yellow) only are subjected to the dot count, for the boundary processing.

10       (Color area discrimination)

          The sections of the color areas are shown in Figure 17.

          An example of color area selection method will be described.

15           The hue direction selection will first be dealt with. Here, the hue direction represents the position on the outermost circumference in Figure 17, that is, the primary color, the secondary color or the intermediate.

20           In Figure 18A, the abscissas are dot counts of the primary color, and the ordinates are dot counts of the secondary color. The classification for the primary color, the secondary color and the indicated color is as follows. The comparison is made between  
25       the dot count of the primary color divided by 2 and the dot count of the secondary color. If the former is larger, the hue thereof is classified into the

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primary color.

The comparison is made between the dot count of the primary color and the dot count of the secondary color divided by 2. If the latter is larger, the hue thereof is classified into the secondary color. Otherwise, it is classified into the intermediate hue.

Then, the chromaticity direction, that is, whether it is close to the center, close to the circumference or in the middle, is discriminated.

Figure 18B shows a sum of dot counts of the primary color and secondary color vs. dot count of the UC (ordinates). The classification in the chromaticity direction is as follows. The comparison is made between the sum of the dot counts of the primary color and the secondary color divided by 2 and the dot count of the UC, and if the former is larger, the chromaticity is closest to the circumference, and the area is determined as the color area of the dot count area.

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The comparison is made between the sum of the dot counts of the primary color and the secondary color divided by 2 and the dot count of UC. If the latter is larger, the comparison is made between the dot count of UC divided by 2 and the sun of the dot counts of the primary color and the secondary color, and if the former is larger, the chromaticity is

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Sub A8 Cont. / closest to the center, and the area is determined as the color area of the dot count area. Otherwise, the intermediate area is selected.

5 The foregoing determination method of the hue and the chromaticity are summarized as follows. (hue direction)

If  $D1/2 > D2$ , the primary color area is selected.

10 If  $D2/2 > D1$ , the secondary color area is selected.

Otherwise, the intermediate hue area is selected.

(Chromaticity direction)

15 If  $(D1+D2) / 2 > UC$ , the high chromaticity area (circumference side) is selected.

If  $UC > (D1+D2) / 2$ , the low chromaticity area (center side) is selected.

Otherwise, the intermediate chromaticity area is selected.

20 In this manner, the color area is finely divided, the differences in the degree of the boundary stripe can be finely dealt with, and the behavior of each of the ink can be taken into account.

(Thinning rank graph)

25 Figures 19A-F show an example of a combination of the rank graphs used in this embodiment.

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In this embodiment, the thinning ranks can be designated for 7 areas (cyan, magenta, yellow, blue, green, red and UC) of the color areas shown in Figure 17, for the respective inks. The thinning rank graph for the intermediate areas other than those, are calculated from the graphs in the 7 areas. By doing so, the number of data of the rank graphs can be reduced.

In an example of calculating the graph, an average between the primary color and the secondary color is taken for the intermediate area in the hue direction, and a higher one of the thinning ranks of the high chromaticity and the low chromaticity, for the intermediate area in the chromaticity direction.

The number of thinning rank graph prepared in this embodiment is  $7 \text{ (color areas)} \times 3 \text{ (the number of links)} \times 2 \text{ (the number of divisions of the thinning area)} = 42$ , in consideration of the designation of the thinning ranks and division of the thinning area into two divisions.

Among them, the thinning rank graphs for the blue color area are actually used when the result of the color area discrimination designates the dot count area of blue color. This is taken out, and is shown in Figures 19A-F. Similarly, the rank graph heads for the red color area is shown in Figures 20A-F.

By the thinning rank graphs and the total dot

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count, the thinning rank to be used in the SMS thinning process is determined.

Thus, the thinning rank graphs are not designated for all the divided color areas, but the basic ones are designated, and the graph is calculated out for the intermediated areas, so that amount of the data can be reduced.

After the rank determination, the SMS thinning process is carried out for the unit areas, similarly to the first embodiment. These processes are carried out for one band, and then, the printing for one scan is carried out.

Referring to Figures 19A, C, the description will be made as to the thinning process in the gradation from the white to the UC (under color, a color mixture of YMC) through the blue (the same as with the foregoing example).

Where the color is toward the blue, the printing is carried out using the cyan ink and the magenta ink, and at the point where the blue is maximum, the cyan and magenta data are indicative of solid print (maximum duty data), that is, level 512 in this example. In the state, the color area of the unit area is blue, and in order to suppress the production of the boundary stripe, rank 5 thinning (Figure 19A) which is high is effected to the cyan lower, and rank 6 (Figure 19C) which is also high is

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effected to the magenta lower.

Referring to Figures 20A, C, the description will be made as to the case of degradation from white through red to UC. Then, the cyan ink is first  
5 started to be used at the point of change from the red at the maximum to the UC. The amount of the ejected ink at that point is the maximum for each of the magenta and yellow colors, similarly to the portion from the blue to the black in the white-blue-black  
10 example, that is, level 512, and the color area is red of course. Therefore, the cyan lower is subjected to the thinning process with rank 3 (Figure 20A) thinning rate, and the magenta lower is subjected to the thinning process with rank 5 (Figure 20C) thinning  
15 rate. At this time, the cyan dots which are sparse other start of the reception of the data, the relatively low rank (rank 3) thinning is carried out, and therefore, no lack of cyan dot is remarkable.

In the first and second embodiments, the used  
20 dot count unit area is 16 dots x16 raster lines (sub-scan direction). However, the size is not limiting, and the size of the unit area is properly determined by one skilled in the art in consideration of the conspicuousness of the boundary stripe, the load added  
25 by the data process, the output resolution or the like.

The position where the SMS thinning process

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is carried out, is not limited to the bottom end portion of the prior scan, but it may be the top end of the later scan, or both, that is, astride the boundary between adjacent bands.

5           It is desirable that most appropriate dot count area and SMS thinning process area can be selected on the basis of combination of the recording material and the recording ink. For this reason, the dot count area and/or the SMS is changeable responding  
10   to the recording material used.

          The number of color areas with the above is two in this embodiment, but the number is not limiting.

          In this embodiment, the one path printing is  
15   the basic mode, since in that mode, the boundary stripe production is most conspicuous. However, the boundary stripe is more or less produced in the multi-path printing. The thinning process is preferable in the multi-path printing with the thinning rank graph  
20   corresponding to the number of paths for the multi-path mode.

          The boundary stripe is caused mainly by the bleeding of the recording ink on the recording material, and therefore, the boundary stripe is more  
25   conspicuous under the high temperature and high humidity ambience since then the degree of the recording ink bleeding is higher. In view of this, it

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is preferable that plurality of threshold levels for switching the thinning rank graph and the thinning area, are provided which are selectable depending on the ambient conditions.

5           In the foregoing embodiment, the recording ink used are cyan, magenta, yellow and black inks. However, the present invention is applicable to the system using so-called photo-ink which is diluted regular ink.

10           In the foregoing description, the data relating to the amount of ejection for each of inks are binary data, but the present invention is not limited to this. The data may be R, B, G multi-level data, if the data correspondent to the amount of the  
15 ink ejected. In this case, the amount of the ink is not limited to the reduction by thinning the data, but may be multiplication of reduction coefficients to the multi-level data.

20           In this embodiment, the use is made with a plurality of colors of ink, and the color area is discriminated for each of the unit areas to determine the proper thinning rate. However, the present invention is applicable to monochromatic recording. Even if a plurality of colors of the ink are used, it  
25 is not necessary to discriminate the color area for each of the unit areas. In this case, the processing for the discrimination process is not necessary.

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### Embodiment 3

The description will be made as to the third embodiment. The structure of the apparatus, the structure of the circuit are the same as with the foregoing embodiments, and therefore, the detailed description thereof is omitted for simplicity.

(Method of correction of boundary stripe)

In this embodiment, the image data corresponding to 5 pixels corresponding in turn to the 5 nozzles at the top end portion in the nozzle arrangement of the recording head and the image data corresponding to 3 pixels corresponding in turn to the 3 nozzles at the bottom end portion in the immediately previous scan, are taken. The data are skipped therefrom. The number of data to be skipped is determined corresponding to the data (dots). As regards the image data at other than the boundary portion, the image data supplied from an external apparatus (host apparatus) are used as they are.

Figure 24 is a flow chart showing the steps of the thinning process; Figure 25 schematically shows a Table for determining the number of dots to be skipped in accordance with the number of ejection data; and Figure 26 illustrates the thinning process using the image data in the image data buffer.

The image data supplied from the host computer (external apparatus) are processed by the

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image data buffer in RAM 105. Of these data, the top 5  
nozzle data constituting the boundary portion are  
processed together with the bottom 3 nozzle data, as  
shown in Figure 26 by data D0. The thinning process  
5 is effected to these data. In Figure 26, one cell  
corresponds to one pixel, and black cell means the  
datum (dot) for which the ink is to be ejected. In  
this embodiment, the image data processed in the  
buffer constitute a binary two-dimensional image plane  
10 for each of cyan, magenta, yellow and black colors.

Therefore, the image data buffer is larger  
than the pixel area for one line of us can by 3 raster  
lines, and as shown in Figure 6 by D0, the data for  
the topmost raster line in the buffer correspondent to  
15 the image data for the third nozzle (254 th nozzle) as  
counted from the bottommost nozzle in the immediately  
previous scanning line. The second raster line from  
the top of the buffer corresponds to the 255 th  
nozzle, the third raster line corresponds to the 256  
20 th nozzle, that is, the bottommost nozzle in the  
nozzle arrangement.

The fourth and subsequent raster lines  
contain the image data to be processed, and the fourth  
raster line corresponds to the topmost, that is, the  
25 first nozzle in the nozzle array. Similarly, the  
fifth raster line corresponds to the second nozzle.  
Subsequently, the sixth-eighth raster lines

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corresponds to the third-fifth nozzles, and they contain the image data corresponding to the boundary area to be subjected to the thinning process.

In Figure 24, at step S41, the dots (ejection data) contained in the image data in the 8 pixels on the first line for the image data of each of the colors, as shown in D1 in Figure 26, is counted, and the total is obtained. In this embodiment, the count corresponding to the total of the dots in the 8 pixels, that is, the number of dots contained in the 8 pixel for the four colors is 4 x the number of pixels, and therefore, it is within the range of 0-32.

Next, the table shown in Figure 25 is referred to, and the number of dots to be skipped is determined depending on the count at step S42. The table in this embodiment, sets the number of dots to be skipped independently of the colors of the ink, but the content of the Table may be changed in accordance with the ink color.

In steps S43, S44 and S45, the addition of the errors and propagation of the errors resulting from the thinning process on the basis of the added errors and from the thinning process to the next row, are carried out.

The rule of thinning for the image data of each color is such that dots of the pixels close to the boundary b are skipped with top priority; when the

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data of different colors are distant from the boundary  
b by the same distance, one of them is skipped in  
consideration of the closeness and the number of dots  
contained in the respective 8 pixels. More  
5 particularly, as shown in Figure 26 by D1, the total  
of the dot counts of the respective colors to be  
processed is 14, and the Table is referred to, and the  
number of skipping dots 5.5 is obtained corresponding  
to the total number 14. As shown in Figure 26 by D2,  
10 the dots are removed from the cyan, magenta and yellow  
with which there are dots in the pixels responding to  
the first nozzles closest to the boundary b. For the  
pixels corresponding to the second and subsequent  
nozzles, the dots are skipped in accordance with the  
15 foregoing rule. As a result, two cyan dots, one  
magenta dot and two yellow dot (five dots in total)  
are removed.

Then, the error  $\delta = 0.5$  remains, which is  
accumulated in an error buffer, and the error is added  
20 in the process for the next row. In the case that  
number of dots to be skipped is larger than the number  
of ejection dots, the number of dots which cannot be  
removed is added to the error buffer. As shown in  
Figure 26, in the thinning process from D2 to D3, the  
25 amount of thinning amount 3.6 provided by the table  
corresponding to the count 11 is added by the error  
0.5 in the process for the previous row, and

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therefore, the thinning amount is 4.1.

<sup>Sub A7</sup> By repeating the above-described the process for each of the rows of 8 pixels, the boundary correction process can be carried out for one line. The process for one line is carried out for each of the scans, by which the density non-uniformity occurring at the boundary between the adjacent scanning record areas, can be suppressed.

In the foregoing description, the image data for which the number of dots discounted includes the area of the immediately previous scan. However, the present invention is not limited to this example. That is, the image data in the immediately previous scanning may be out of consideration, the dots may be counted in the data corresponding to the first to fifth nozzles to the boundary.

The thinning process according to this embodiment is summarized as follows.

i) The ejection dots in the area (row) to be thinned are counted for each color, and the order of accounts is determined. The Table is looked up, and the number of dots to be skipped is determined on the basis of the total of the counts.

In the example of Figure 26, (yellow= 6) > (cyan= 5) > (magenta= 3) > (black= 0), and the number of dots to be skipped is determined as being 5.5 from the Table of Figure 25.

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ii) the comparison is made between the number of ejection dots in the pixel closest to the boundary of each color and the number of dots to be skipped obtained above, and if the number of dots to be  
5 skipped is larger, all of the dots are removed. On the other hand, the number of dots to be skipped is smaller, the thinning is effected from the color with which the number of ejection dots is larger in accordance with the order described above.

10 In the example of Figure 26, the cyan, magenta and yellow data contain the ejection dots in the pixels corresponding to the first nozzle, that is, the pixels closest to the boundary (the number of ejection dots in the pixels closest to the boundary is  
15  $3) < (\text{the number of dots to be skipped is } 5.5)$ , and therefore, the dots are all disabled from such pixels. By doing so, 1 dot is removed from each of the cyan, magenta and yellow pixels which are closest to the boundary.

20 iii) The number of dots to be skipped is deducted by the number skipped in the process ii). As a result, when the number of dots to be skipped is one or more, the process in the ii) is repeated. On the other hand, if the number of dots to the skipped  
25 becomes one or less, the number of dots to be skipped is added to the error buffer, and the process proceeds to the next area.

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In the example of Figure 26, the number of dots resulting from reducing by the number skipped in the process ii) is 2.5, and since (the number of ejection dots in the pixels closest to the boundary is 3) > (the number of dots to be skipped is = 2.5), and therefore, the dots are disabled from the second yellow pixel and then from the second cyan pixel. As a result, the error becomes 0.5.

By doing so, 2, 1, 2 dots are skipped from the cyan, magenta and yellow pixels, respectively. Then, the final error is 0.5 which is added to the error buffer, and the process proceeds to the next row.

(Fourth embodiment)

In the third embodiment, the amount and way of thinning is common to all of the colors. In this embodiment, the amounts of the thinning are different depending on the kinds of or colors of the ink.

The density non-uniformity in the form of a stripe is produced due to the penetration of the ink into the recording material, described herein before. However, it is relatively difficult to make the perviousnesses of all of the inks relative to the recording material uniform, because of the differences in the dye in the ink and the preservation property and the ejection stability. On the other hand, the density non-uniformity at the boundary between the

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adjacent scans are dependent on the total ejected ink amount for all colors. Therefore, the proper correction is difficult even by setting correction tables for the respective inks and determining the amount of thinning for the respective inks. In this embodiment, weighting is imparted depending on the inks (the perviousnesses) when the dots are counted.

More particularly, in view of the fact that perviousness of the yellow ink is low, the dot count for the yellow is multiplied by 0.5. By doing so, the density non-uniformity in the form of a stripe at the boundary between adjacent scans can be suppressed. (Another embodiment)

When the use is made with a recording head capable of modulation in the amount of the ink ejected from the nozzle, the amount of the ink may be controlled utilizing the modulation. (Others)

The present invention is very effective when used with an ink jet recording system, in particular, when used with an ink jet recording head which comprises a means for generating thermal energy (for example, electrothermal transducer, or a laser) used for ejecting ink, and in which the state of ink is changed by the thermal energy, and also a recording apparatus employing such an ink jet recording head. This is due to the fact that according to such a

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recording system, recording can be made at high density, and a highly precise image can be formed.

The present invention is particularly suitably usable in an ink jet recording head and recording apparatus wherein thermal energy by an electrothermal transducer, laser beam or the like is used to cause a change of state of the ink to eject or discharge the ink. This is because the high density of the picture elements and the high resolution of the recording are possible.

The typical structure and the operational principle are preferably the ones disclosed in U.S. Patent Nos. 4,723,129 and 4,740,796. The principle and structure are applicable to a so-called on-demand type recording system and a continuous type recording system. Particularly, however, it is suitable for the on-demand type because the principle is such that at least one driving signal is applied to an electrothermal transducer disposed on a liquid (ink) retaining sheet or liquid passage, the driving signal being enough to provide such a quick temperature rise beyond a departure from nucleation boiling point, by which the thermal energy is provided by the electrothermal transducer to produce film boiling on the heating portion of the recording head, whereby a bubble can be formed in the liquid (ink) corresponding to each of the driving signals. By the production,

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development and contraction of the the bubble, the liquid (ink) is ejected through an ejection outlet to produce at least one droplet. The driving signal is preferably in the form of a pulse, because the development and contraction of the bubble can be effected instantaneously, and therefore, the liquid (ink) is ejected with quick response. The driving signal in the form of the pulse is preferably such as disclosed in U.S. Patents Nos. 4,463,359 and 4,345,262. In addition, the temperature increasing rate of the heating surface is preferably such as disclosed in U.S. Patent No. 4,313,124.

The structure of the recording head may be as shown in U.S. Patent Nos. 4,558,333 and 4,459,600 wherein the heating portion is disposed at a bent portion, as well as the structure of the combination of the ejection outlet, liquid passage and the electrothermal transducer as disclosed in the above-mentioned patents. In addition, the present invention is applicable to the structure disclosed in Japanese Laid-Open Patent Application No. 123670/1984 wherein a common slit is used as the ejection outlet for plural electrothermal transducers, and to the structure disclosed in Japanese Laid-Open Patent Application No. 138461/1984 wherein an opening for absorbing pressure wave of the thermal energy is formed corresponding to the ejecting portion. This is because the present

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invention is effective to perform the recording operation with certainty and at high efficiency irrespective of the type of the recording head.

In addition, the present invention is applicable to a serial type recording head wherein the recording head is fixed on the main assembly, to a replaceable chip type recording head which is connected electrically with the main apparatus and can be supplied with the ink when it is mounted in the main assembly, or to a cartridge type recording head having an integral ink container.

The provisions of the recovery means and/or the auxiliary means for the preliminary operation are preferable, because they can further stabilize the effects of the present invention. As for such means, there are capping means for the recording head, cleaning means therefor, pressing or sucking means, preliminary heating means which may be the electrothermal transducer, an additional heating element or a combination thereof. Also, means for effecting preliminary ejection (not for the recording operation) can stabilize the recording operation.

As regards the variation of the recording head mountable, it may be a single corresponding to a single color ink, or may be plural corresponding to the plurality of ink materials having different recording color or density. The present invention is

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effectively applicable to an apparatus having at least one of a monochromatic mode mainly with black, a multi-color mode with different color ink materials and/or a full-color mode using the mixture of the colors, which may be an integrally formed recording unit or a combination of plural recording heads.

Furthermore, in the foregoing embodiment, the ink has been liquid. It may be, however, an ink material which is solidified below the room temperature but liquefied at the room temperature. Since the ink is controlled within the temperature not lower than 30 SUPo/SUPC and not higher than 70 SUPo-/SUPC to stabilize the viscosity of the ink to provide the stabilized ejection in usual recording apparatus of this type, the ink may be such that it is liquid within the temperature range when the recording signal is the present invention is applicable to other types of ink. In one of them, the temperature rise due to the thermal energy is positively prevented by consuming it for the state change of the ink from the solid state to the liquid state. Another ink material is solidified when it is left, to prevent the evaporation of the ink. In either of the cases, the application of the recording signal producing thermal energy, the ink is liquefied, and the liquefied ink may be ejected. Another ink material may start to be solidified at the time when it reaches the recording

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material. The present invention is also applicable to  
such an ink material as is liquefied by the  
application of the thermal energy. Such an ink  
material may be retained as a liquid or solid material  
5 in through holes or recesses formed in a porous sheet  
as disclosed in Japanese Laid-Open Patent Application  
No. 56847/1979 and Japanese Laid-Open Patent  
Application No. 71260/1985. The sheet is faced to the  
electrothermal transducers. The most effective one  
10 for the ink materials described above is the film  
boiling system.

The ink jet recording apparatus may be used  
as an output terminal of an information processing  
apparatus such as computer or the like, as a copying  
15 apparatus combined with an image reader or the like,  
or as a facsimile machine having information sending  
and receiving functions.

As described in the foregoing, according to  
the embodiments of the present invention, the unit  
20 area in which the ink ejection amount is counted is  
astride the boundary between the adjacent bands, and  
the situation at the boundary can be properly  
predicted.

By using different sizes for the dot count  
25 area and the thinning area, appropriate thinning is  
possible.

While the invention has been described with

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reference to the structures disclosed herein, it is  
not confined to the details set forth and this  
application is intended to cover such modifications or  
changes as may come within the purpose of the  
5 improvements or the scope of the following claims.

Thus, the thinning area can be properly  
selected, and therefore, the production of the banding  
can be effectively suppressed.

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